

Culture Management on the NASA Hubble Space Telescope Control Center Reengineering Project

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Introduction—HST Vision 2000 Program

In 1995, the NASA Goddard Space Flight Center instituted the Vision 2000 Project to reengineer the ground-based control system for the Hubble Space Telescope (HST). The project's main purpose was to significantly reduce the costs of operating the telescope through the remainder of its lifetime (until approximately 2010), without impacting ongoing scientific observations. The new control system would primarily achieve these goals by utilizing state-of-the-practice technologies to automate routine, manually intensive functions.

To streamline the development process, the HST organization chartered a Product Development Team (PDT) to reengineer the existing business processes and computer systems to create the new Control Center System (CCS). The CCS PDT was envisioned as a "badgeless" team comprised of a mixture of NASA civil servants and multicontractor staff, dedicated to a common goal. A key component to the success of the PDT approach was to integrate domain and technology experts, including the end users, developers, testers, network and security engineers, and system engineers/integrators, into a highly cohesive team.

The HST organization imposed a couple of additional constraints upon this effort. First, the new system would be developed using as many of the maintenance staff for the existing system as possible. Second, the new system would be implemented using a methodology based on Integrated Product Teams (IPT) and would emphasize *radical change* versus *incremental evolution* in system operations. Third, the new system must be fully operational in time to support the third HST Servicing Mission now scheduled for early fall 1999. Individually, none of these constraints was troublesome, but together they would induce several interesting management challenges. It was from within this project environment that the concept of "culture management" evolved.

Culture Management

In order to be successful, corporations and institutions have long recognized the importance of applying tailored project management practices to their ongoing

projects. However, the CCS Reengineering Team discovered that it was necessary to establish a facet of project oversight that complemented the classical task and resource views: "*culture management*." By culture management, we refer to the recognition and application of the sum total of the experience, knowledge, goals, behavior, and communications by each member of the project to form an integrated community. Due to the constraints imposed on it, the CCS project inherited numerous *de facto* cultures and subcultures from the support contractor organizations, each with its own way of doing business.

Culture management primarily strives to address job satisfaction and deals with establishing and maintaining a unified environment that supports optimal personnel performance within established resource and schedule constraints. Specifically, it establishes common goals, values, attitudes, knowledge, and practices within the organization. But culture management is not static. Over time, its elements must evolve to maintain optimal benefit for all participants. Culture management *is required* when multiple organizations with differing approaches to problem solving are brought together to achieve a common goal. It became critical to the CCS project since it was comprised of over a dozen contractor companies and NASA civil servants from multiple organizations. Applying culture management principles, the CCS project established a synergistic environment where the technical staff grew into a highly integrated team with well-defined and endorsed common goals. The importance of people to strong cultures cannot be understated: "Successful corporate cultures result from the thoughts, intentions, and energy of everybody in the organization. While managers naturally have a greater influence on the process, there are people inside every organization who set the tone for the way the organization works" (James 1996, xvi).

The remainder of this paper details the evolution of culture management within the CCS project over a multi-year period. Although this paper presents many of the positive results, the authors wish to stress that many of the culture management activities required trying multiple approaches to achieve the desired results and that, in some cases, the results were almost accidental. The information

is presented chronologically, starting with the kickoff for the CCS reengineering effort and proceeding through four distinct phases of the project. It should be noted that the following phases were not discrete, but actually represent snapshots of a gradual, *evolutionary process* at specific points in time.

The Early Days: Order from Chaos

About the time the CCS reengineering effort was getting underway, a survey of project managers was made public (Zells 1996). It revealed that of project managers surveyed, *only* 15 percent of them had successful projects, 52 percent of their projects cost twice their original estimate, and 33 percent of their projects were never finished. This was not the type of encouraging news that the CCS project management team needed as they embarked on a very ambitious project of reengineering the entire HST ground system.

One of the first issues encountered was that a *de facto* culture already existed within the organization. This culture had established itself over the previous ten years of spacecraft operations. Because this culture had crystallized areas of contractual responsibility and supported well established inter-contractor and government-contractor interfaces, attempts to change this structure directly would surely fail. Therefore, a less direct approach would be necessary to establish a new culture that would enable radical change. The approach taken was to identify a core of technical and management personnel to act as the vanguard for the new system development. This core consisted of a handpicked combination of new personnel and existing domain experts. New personnel were selected for their expertise in system development processes and methods, while the existing personnel were selected for their understanding of spacecraft operations. After some initial faltering on the part of the core team, the members were collocated in a single area to facilitate communications and to reduce the time frames needed to identify issues and to make decisions. This action greatly enhanced the productivity of the team and helped form the seed for the new culture.

The initial activities of the collocated core team established what turned out to be the cultural underpinnings for the project. For example, one of the first tasks was to formalize and document the detailed goals of the system reengineering effort. This task was part of a significant business process reengineering (BPR) effort that resulted in the establishment of a new operations concept for HST spacecraft operations. Specifying and maintaining a common set of project goals provided a big picture that was

used by the staff throughout the remainder of the project to understand their specific contributions to the whole. In addition, the new operations concept contained the beginnings of a project-specific vocabulary that helped to differentiate and encapsulate the reengineering effort from the existing maintenance culture.

Another task of the core team was defining many of the system analysis, design, development, and test philosophies that would be in place throughout the remainder of the project. Selecting the appropriate engineering methods for the various pieces of the target system (e.g., spiral versus waterfall, structured analysis versus object oriented) and then procuring the necessary infrastructure and tools to support these methods was then undertaken. The purpose of this task was to acquire and install a suite of hardware and software components that would provide the beginnings of an integrated development environment to be used by the entire staff. The establishment of a single development environment for systems, hardware, software, database, network, and test engineers would help provide a common foundation for discussion and exchange of ideas. An intensive training effort was organized to familiarize incoming staff members with the various facets of the project already instituted by the core team.

Although these activities are typical for startup projects, they were challenging for the CCS reengineering effort for a couple of reasons. First, each supporting organization already had its own processes, methods, standards, and project management plans with which they were familiar. The core team chose to generate the corresponding CCS foundation products by integrating the best of breed available from existing contractor manuals and government standards. Second, because members of the core team had different backgrounds, they did not fully appreciate each other's experience and skills. Having the core members collocated and working as a team quickly abated this issue. An unexpected benefit was that the members of the team began to cross-train each other in their areas of expertise. This resulted in a highly cohesive core team whose members were able to assume leadership roles throughout the remainder of the project.

Because there was some ongoing resistance to the concept of radical change within the HST organization, a strong management commitment was necessary to reach the point where the reengineering effort could start in earnest. The management-oriented members of the core team elected to implement an internal matrix management structure where each staff member belonged to a specific functional group but supported one or more IPTs. This arrangement facilitated the dissemination of system development information across the teams.

The Initial Organization: A Federation of Individuals

With a management structure in place, the project development phase commenced. One of the critical activities was to begin the staffing of the project with team leads and technical personnel. This activity turned out to be more difficult than expected. First, the available candidates consisted of those persons who had been maintaining the existing system. Though they were technically qualified, many were not familiar with the goals of this reengineering effort and lacked experience with current design methods and practices (e.g., Object Modeling Technique). In fact, some of the contractors hesitated to provide their most qualified persons because they were not convinced that their most valuable personnel assets would adequately benefit from supporting this radical project. Some of the candidates actually harbored cultural biases against the project because it proposed to change business processes with which they had become very comfortable. These attitudes were most noticeable in the consistent use of the “I” and “you” pronouns during informal intra-staff discussions, indicating that these persons did not consider themselves to be members of the CCS “team.” It was apparent that significant changes in some individual attitudes needed to be adjusted if this project was to succeed.

To mitigate these risks, a process of cultural indoctrination was begun. This process consisted of a combination of intensive training and team-oriented activities. The training effort initially focused on providing the staff with an understanding of CCS system goals, both immediate and long term. This established a common vision and reinforced the fact that everyone would directly contribute to the success or failure of the project. The training efforts were expanded to address the basic technologies, including training on development methods, standards, tools, and processes to be used in the design of CCS. This training provided a foundation between the functional teams by supplying a common understanding and vocabulary that quickly became a significant cultural underpinning for the remainder of the project. A second wave of the technology training was arranged that addressed areas associated with system implementation (e.g., Java and C++). As the supporting contractors received positive feedback from their personnel they became willing to make more senior members of their organization available to this project.

While some members of the staff were taking advantage of the training opportunities, others were tasked with defining several of the key architectural facets of the tar-

get system (e.g., networking, security, data distribution/management, and functional). Integrated Product Teams were formed by assigning members of appropriate functional teams to each of the major architectural areas. When a required expert could not be identified, outside consultants were temporarily acquired to support that team. Staff members were given reasonable flexibility in their assignment to specific IPTs based on their interests and background. When issues arose within an IPT, a member of the technical core would be temporarily added to that team, acting purely as a facilitator. In general, the IPTs were empowered to make (and then justify) decisions concerning their facet of the system. This empowerment was another key element of the stability and growth of the CCS culture, with staff members given opportunities to make a real contribution to the project.

Concurrent with the training and architecture efforts, other project management activities were undertaken. First, in order to facilitate communication and reduce the impact of unwanted outside influences, a collocation facility was acquired to house the entire project staff. Others have concluded (Parker 1994) that collocation contributes to team effectiveness because it brings strangers together, diminishes past problems, and facilitates new relationships. The system development infrastructure (e.g., networks, engineering workstations and servers, E-mail, design tools) was installed in the facility to provide the staff with access to a common administrative and system-development environment. Although the collocation of the project staff had many benefits, it was not well received by all the supporting contractors. Their concerns dealt primarily with their inability to supervise the tasks that their employees were performing to ensure the generation of quality products. The compromise that was reached enabled the contractor managers to monitor the activities of their personnel in the collocation facility. Day-to-day direction for the staff members would be provided by their functional team leads within the CCS project.

With the entire technical staff located in one place, a level of informal communication and camaraderie was possible. To exploit this opportunity, project management instituted periodic “social events” in recognition of work well-done, and also to allow the staff to interact on a more personal level. These events included pizza parties, cook-outs, and holiday celebrations. These social mixers provided an informal environment where people could interact outside of the formal work setting, could discuss issues in a more relaxed environment, and served to reinforce the fact that everyone was part of the same team.

In spite of these efforts to promote a synergistic team-oriented environment, it became apparent that there were some individuals who were not functioning well. In these

cases, some individuals were given the option to transfer to another functional team within the project, while others were asked to leave the project. Although the dismissal of persons from the project increased the overall attrition rate and resulted in the loss of some trained and knowledgeable engineers, the net result seems to have been positive. This is because these individuals were either not contributing to the project or their presence was disruptive to other members of the team. Their replacement with persons who could better assimilate into the culture appears to have produced a stable project membership over the longer term.

The Badgeless Society

Over a relatively short time frame, it was possible to watch the staff evolve from a group of individuals into a highly productive team, which was referred to as the *badgeless society*. This badgeless society had many of the characteristics of a virtual company, where the entire staff assumes some responsibility for the quality of the generated products and directly contributes to the success of the project, regardless of what organization to which they actually belonged. In a couple of cases, this led to the previously unheard-of situation where contractors were directing the daily activities of government personnel.

With the positive feedback produced by this evolution in culture, it became much easier to fill new staffing slots. In general, these slots required less senior individuals, and contractors often submitted new hires to fill these roles. This situation had an unexpected benefit in that less experienced individuals were more open to the tenets of the CCS culture than the original staff members had been. This helped minimize the management efforts needed to maintain the established culture.

Around this time, the project was reaching the point in which incremental releases of the system were being deployed. Project schedules gained higher visibility both inside and outside the organization, which served to increase the pressure to succeed. As a result, the functional groups within the project coalesced through the interaction of the IPTs. This became apparent through the existence of informal peer-to-peer communications channels in addition to the formal channels associated with the management structure. These informal communications channels served to increase productivity by reducing the time needed to identify and resolve minor development issues. This enhanced productivity seemed to increase the level of enthusiasm on the project, in spite of the long hours being worked by the staff. Specifically, during this time the software development productivity exceeded twice the typical industry standards (on a sloc/hour basis) with comparably low error rates.

On the technical side, the project culture was reinforced by the ability of any member of the staff to identify and track technical issues with the system. A formal mechanism was implemented where anyone could document a potential design or implementation problem. All issues were reviewed by the technical core and were then either assigned to an IPT lead for resolution or rejected for specified reasons. This process conveyed a level of ownership of the system to the staff members and, thus, increased their commitment to its success. In spite of the tight schedules, time was set aside each week for technical demonstrations of some technology being used in the system. These demonstrations (often to senior managers) provided a mechanism to reinforce the vision and goals of the project, to provide some informal training, and to establish the identity of experts in specialized areas. All of these activities served to maintain high morale, which resulted in maintaining high productivity on products with excellent quality. For example, the Release 1.0 of the CCS system was used the day it was installed to troubleshoot a potential problem with one of the science instruments in the HST satellite.

The primary goal of project management during this period was to ensure that each release of the system was developed and deployed on schedule. Often the system functionality requested by the end users for a specific system release exceeded the available project resources. In these cases, the management staff negotiated with the end users to define a mutually acceptable level of functionality within time and resource constraints. The results of the negotiations would then be presented to the technical staff for concurrence and identification of issues. This resulted in the technical staff informally "buying-in" to the scope and schedule for a specified release. It then became a matter of pride to meet their commitments. This is in contrast to classical project management in which the engineers often have limited input into the scope and schedule of their assigned tasks.

Several other management activities were undertaken during this time frame to support the highly cohesive culture that had formed. First, an independent external organization was identified to monitor and track the quality of the software products being generated. The results of the independent assessment were extremely positive, showing that the staff was indeed turning out high quality products with a very low defect rate. In fact, the metrics generated from the CCS software were subsequently used as a benchmark against which other similar projects were compared. In those areas where improvement was possible, a "process improvement" exercise was applied to the underlying methods and processes to eliminate non-value-added steps or to bolster areas where errors could creep into the system. It should be noted that this process

improvement exercise was ongoing throughout the project and was not a one-time activity.

Because of the high level of commitment and trust demonstrated by the staff in meeting aggressive schedules, the management chose to compensate the staff to the greatest extent possible. For starters, project management worked with government representatives outside the project and with the contractors to provide monetary bonuses. Other rewards provided to the staff concentrated on career development opportunities that included additional training in project-specific technologies and vendor products. Members of the staff were encouraged to write papers about various aspects of the CCS project and to attend related conferences and symposia. The CCS social events continued through this phase of the project as a way of encouraging the informal communication channels that had developed. At this point, the CCS team had evolved into a highly efficient, mutually supportive, and trusting organization. Concerning the trust factor: "Trust is the pathway to open communications; its absence can undermine a team's effectiveness. On some cross-functional teams, conflicts exist but do not surface because members do not feel free to express their opinions or share their expertise" (Kinlaw 1991).

Maintaining and Advancing the Culture

As the CCS system began to be used to operate the spacecraft, two culture management challenges emerged: maintaining the culture that had evolved within the project and exporting part of that culture into the end user community. These challenges were complicated by several factors. The first was the fact that the project was beginning its transition from a development-oriented to a maintenance-oriented effort. This transition could require significant changes in the policies and procedures upon which the CCS culture had been built. In addition, the staff had been working excessive hours for an extended period of time. The possibility of burnout, leading to increased attrition, had to be addressed. Last, migrating the system into its operational environment required the staff to interact with individuals who were still part of the original system culture. The tendency to revert back to a less aggressive, risk avoidance approach to system deployment and maintenance could impact staff effectiveness.

Although initially a concern, the gradual transition of the project from development to maintenance was less problematic than expected. In fact, a significant portion

of the CCS staff was already familiar with basic maintenance paradigms from the years they had spent working on the predecessor system. In addition, the informal lines of communication that had been established across the project aided initial maintenance activities by rapidly identifying system dependencies associated with each required change. There were some changes required to the established development-oriented methods and procedures in which the users had been trained. However, these reflected a reasonable modernization of the methodologies with which the staff was already comfortable. It is believed that allowing members of the staff to transition from development to maintenance will help keep them technically challenged and may help some individuals avoid burnout.

As the various releases of the operational CCS system were deployed, interaction between the CCS staff and the end user community was worrisome. This was based on the perception of a nontrivial cultural rift existing between the two organizations. In an attempt to bridge this rift, some CCS staff members became active participants in the deployment and maintenance activities to transfer an understanding of the CCS philosophies and approaches to the end users. However, to prevent the staff members from being assimilated back into the older operations culture, they continued to maintain a significant presence in the collocation facility. On the other hand, key members of the user community were continually invited to various IPT working groups and technical meetings within the collocation facility. This exposure helped reinforce their understanding of the processes used in the development and deployment of the system and helped make them "a part of the solution." This two-pronged approach enabled the successful deployment and use of the developed system. Over time, the cultural biases eroded, and many of the end users began to openly prefer CCS to the predecessor system.

The results of establishing, maintaining, and eventually advancing the culture to the end user community has provided several significant and quantifiable results. First, the CCS project has maintained an incredibly low attrition rate, running about 5 to 8 percent annually. Moreover, several members of the staff who left after an initial tenure have actually returned to the project. Second, independent external reviews of the engineering products generated on the project continue to show a high quality level, with low error rates. Third, several staff members have received special recognition from their contractor organizations, regarding advancements they made in state-of-the-practice in ground systems development. These results are due to some degree to the effective management of the

synergistic and cohesive culture that existed within the CCS development environment.

Conclusions

This paper presented a case study for the management of an integrated, dynamic organization versus that of individuals or fixed groups. More importantly, the evolution and management of a culture that maximizes, emphasizes, and extends the human element of a project paid big dividends in terms of overall quality, productivity, and commitment. The paper introduced the term “culture management” (as an adjunct to task and resource management) to describe the set of processes and activities that contributed to the development and sustenance of a cohesive, people-centric organization. One author asserts that strong cultures improve performance because they create an unusual level of motivation in employees, that shared values and behaviors make people feel good about working for a firm, and that feeling of commitment or loyalty then makes the work intrinsically rewarding (Kotter 1992).

As part of this cultural evolution, what became critical to the success of the CCS reengineering project was the evolution of a “mutual commitment” by all members of the project. This commitment gradually transformed it from an isolated collection of technical and domain experts to a tight-knit, united community (or a “virtual company”). The strong sense of community spirit that prevailed within the CCS team differentiated it from, and enabled it to surpass, previous, comparable development projects. Indeed, this sense of community feeling led the team to strive to be the best, which in turn provided a common direction, joint satisfaction, and a strong binding effect characteristic of the American small towns of the past (DeMarco 1987).

This culture management approach was enabled through the effective use of integrated product teams, coupled with a fluid management structure that was driven by continuous process improvement principles. Indeed, the success of the project can be directly attributed to enabling a common culture that supported and enhanced each individual’s contribution to the whole, and by doing so, what coalesced was a highly productive, loyal team. The primary remaining issue with respect to culture management is how to return the members of the project staff back to their corresponding contractor environments without inducing significant culture shock on both sides. This case study has also shown that it is incumbent upon the Project Manager to assume an active role in cultivating the project by inte-

grating “soft skills” with the appropriate leadership and vision to manage the culture. With this more comprehensive project management approach, the project may greatly exceed its expectations.

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